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A SURVEY AND REVIEW OF INFORMATION PERTAINING TO CHEMICAL USE IN ASSOCIATION WITH CONSERVATION TILLAGE ON THE CANADIAN PRAIRIES

Prepared by:

Monenco Consultants Limited
for Environment Canada
Conservation & Protection
Environmental Protection
Western & Northern Region

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Pertaining to Chemical Use in
Association with Conservation Tillage
on the Canadian Prairies

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READERS COMMENTS

Readers who wish to comment on the content of this report should address them to:

Liz Gordy
Scientific Programs Branch
Environmental Protection
Conservation & Protection
Western & Northern Region
Room 210, Twin Atria
4999-98th Avenue
EDMONTON, Alberta
T6B 2X3

EXECUTIVE SUMMARY

This study was initiated to obtain information on the expected shifts in weed and pest populations, and associated chemical use patterns, in response to a shift from conventional to conservation tillage methods on the Canadian Prairies.

The study revealed that a change from conventional to conservation tillage techniques will probably cause a shift in weed populations from annual to perennial species, and a shift from preemergence to postemergence herbicides.

The herbicides expected to be utilized in Western & Northern Region, as part of a conservation tillage regime are 2,4-D, dicamba and glyphosate. The study results did not clearly define a shift in insecticide and fungicide use associated with conservation tillage practices.

TABLE OF CONTENTS

		Page
1.0	INTRODUCTION	1
	1.1 Objectives	2
	1.2 Methods	2
2.0	INFORMATION OBTAINED FROM PUBLISHED LITERATURE AND INTERVIEWS	3
	2.1 Terminology - Literature	3
	2.2 Terminology - Questionnaire/Interviews	4
	2.3 Estimate of Current and Future Percentage of Cropland Under Conservation Tillage	4
	2.4 Types of Conservation Tillage Methods Currently Used	5
	2.5 Consequences of Increased Conservation Tillage Related to Weed Species and Herbicide Use	9
	2.6 Consequences of Increased Conservation Tillage Related to Insect Pests	17
	2.7 Consequences of Increased Conservation Tillage Related to Plant Diseases	18
3.0	CONCLUSIONS	19
4.0	REFERENCES	21

TABLES

Table		
1	Frequency of Reported Cropland Currently Under Some Form of Conservation Tillage	6
2	Frequency of Reported Cropland Estimated to be Under Some Form of Conservation Tillage in Five Years	7
3	Estimates of the Forms of Conservation Tillage Currently in Use	8
4	Representative Herbicides Used in Conservation Tillage Systems	12
5	Frequency of Reported Chemical Herbicide Use on the Canadian Prairies	13
6	Herbicides Anticipated to be More Widely Used (With Frequency of Responses) With Increased Conservation Tillage	16

APPENDICES

APPENDIX A: Bibliography from Data Base Searches

APPENDIX B: Questionnaire and Mailing List

APPENDIX C: Individuals Contacted by Telephone

1.0 INTRODUCTION

In 1985 Environmental Protection, Western & Northern Region prepared a report entitled Implications of Reduced and No-Tillage Systems on Chemical Use in the Prairie Provinces (EPS, 1985). It has been well documented that reduced and no-tillage systems substantially reduce soil erosion by wind and water. As a result, the transport of nutrients and herbicides from the target areas to surface waters is greatly reduced compared to conventional tillage. The 1985 EPS study was initiated to obtain background information on the implications of reduced and no-tillage systems on chemical use in the prairie provinces.

The study revealed that very few reduced and no-tillage systems existed in the prairie provinces in 1985. The high cost of herbicides and the need for improved farm management were cited as the limiting factors. The southern regions of the prairie provinces were shown to have the greatest potential for reduced and no-tillage farming. Changing from conventional to reduced or no-tillage systems was shown to cause a shift in weed spectrums that favored the growth of perennial weeds. The use of herbicides was expected to increase with reduced, and particularly no-tillage systems, and postemergence herbicides capable of controlling perennial weeds were expected to exhibit the greatest increase.

The 1985 study alerted Environmental Protection to the possibility of a changing spectrum of chemical use in Western & Northern Region, but did not address which specific herbicides would be expected to enter the environment under conservation tillage regimes. In order for Environmental Protection to supply advice and recommendations for incorporation into a sound general position on conservation tillage, specific herbicides need to be determined so that the environmental impact of chemical use in response to conservation tillage practices can be predicted.

This report is based on a study, performed by Monenco Consultants of Calgary, to determine the specific types of chemicals expected to be utilized by farmers on the Canadian Prairies who are presently practicing some form of conservation tillage.

1.1 Objectives

The objective of this information review was to determine expected types and amounts of specific chemicals that will be associated with a shift from conventional to conservation tillage practices on the Canadian Prairies. To accomplish this, a review of pertinent literature and a series of telephone and questionnaire interviews with persons directly involved in the agricultural industry were initiated to identify the following:

Expected alterations or shifts from the present patterns of weed, insect and biological diseases associated with a shift from conventional tillage to conservation tillage practices;

Specific chemicals that are presently incorporated or will be incorporated in both conventional and conservation tillage practices; and

Quantities of chemicals presently utilized in conventional tillage practices and the relative quantities expected as a result of the increased practice of conservation tillage.

1.2 Methods

A comprehensive search of the technical, scientific and popular literature was conducted by using the following computerized data bases:

Agricola;
Aquatic Sciences and Fisheries Abstracts;
Biosis Previews;
Enviroline;
Environmental Bibliography;
National Technical Information Service;
Pollution Abstracts;
Waternet;
IEC, ELIAS, NCRPUBS, AQUAREF, ICAR (CAN/OLE); and
CAB Abstracts.

The key words used in these computerized data base searches were conservation tillage, minimum tillage, limited tillage, reduced tillage, no-tillage, zero tillage and chemical fallow. The data base QL Systems was not searched as it deals primarily with legal documents, mining reports and northern development. A search of the library collections, mainly federal, was based on information about books and other published documents derived from the computerized data base searches. A bibliography derived from this literature search is presented in Appendix A.

A questionnaire was also sent out to district agriculturalists located in the provinces of Alberta, Manitoba and Saskatchewan. The questionnaire and mailing list are presented in Appendix B. Insufficient returns were received to draw conclusions based on the questionnaire responses. In addition to the questionnaire, a number of individuals concerned with agriculture and agricultural chemicals were contacted by telephone to discuss the impacts of the shift to conservation tillage. A list of these individuals is presented in Appendix C.

2.0 INFORMATION OBTAINED FROM PUBLISHED LITERATURE AND INTERVIEWS

2.1 Terminology - Literature

While terminology related to tillage systems exhibited some variation in the literature, there was usually enough consistency in the use of most terms for a relatively easy assessment of the amount of soil disturbance associated with each tillage system.

Conventional tillage was usually associated with the use of the moldboard plow, which effectively buries the plant material near the soil surface. Traditionally, the use of the moldboard plow might be followed by disking three or four times and then harrowing to provide a smooth soil surface prior to planting. Row crops (e.g. corn, sugarbeets, potatoes, tomatoes) would also be subjected to continued tillage just before or at emergence and perhaps two to four times after emergence.

By contrast, conservation tillage practices varied widely in the amount of soil disturbance practiced and with the crop cultivated. Mulch tillage, often referred to as reduced tillage or minimum tillage, and often used by small grain producers, generally referred to systems which disturbed the soil surface, but left some minimum plant residue (30% was a common criteria) on the soil surface. Ridge-till systems for row crops allowed undisturbed soil prior to planting, but with one-third of the soil surface tilled at planting. Planting was completed on ridges constructed and maintained by tillage. No-tillage systems, also referred to as zero tillage or chemical fallow, leave the soil undisturbed prior to planting. At planting, the surface residue and soil or sod is split open for a narrow seed bed and then closed again.

Additional descriptions of tillage nomenclature are provided by the Soil Conservation Society of America (1982), Mannering and Fenster (1983), Siemens et al. (1985) and Allen and Fenster (1986).

2.2 Terminology - Questionnaire/Interviews

In discussions with interviewees and reading the responses of various agriculturalists, it was evident that a wide variety of definitions are applied to the term "reduced tillage", which is only one of the many concepts covered by conservation tillage. From the view point of some agriculturalists, it appeared that the elimination of just one conventional tillage operation during a year would constitute "reduced tillage." However, the covering letter, which accompanied the questionnaire, defined the term "conservation tillage" to also include minimum tillage, limited tillage, no tillage, zero tillage and chemical fallow. By using this range of tillage concepts, it was hoped that a distinction between true conservation tillage practices and slightly modified conventional tillage would be made by the respondents. For the most part, this seems to have been the case in the questionnaire responses.

2.3 Estimate of Current and Future Percent of Cropland Under Conservation Tillage

Despite the wide and varying definitions of conservation tillage, most of the respondents indicated that conservation tillage was practiced on between 0 to 10% of the cropland in their districts (Table 1).

Not all respondents could estimate what percentage of cropland would be under conservation tillage in five years. Those respondents who did make an estimate appeared to show a shift away from the 0-10% category and toward a range of 21-30% (Table 2). However, several respondents warned that the future use of conservation tillage in their district was heavily dependent on future weather conditions, particularly precipitation. If annual precipitation increased over the next few years, some respondents stated that conservation tillage practices might actually decrease.

2.4 Types of Conservation Tillage Methods Currently Used

A wide variety of answers were given by the respondents when asked about the different types of conservation tillage methods currently used. Some of the replies were related to the amount of vegetative matter (e.g. stubble) remaining on the field after tillage or to particular types of tillage machinery. A sufficient number of the respondents used the categories presented in Table 3 so that ranges, median and average values for each of the conservation tillage types could be determined. Relatively few high values for reduced and minimum tillage tended to skew the arithmetic average values upward. The geometric mean or median was a more appropriate indication of central tendency for the categories in Table 3. Reduced tillage seems to be the most widely used category of conservation tillage, probably due in part to differences among agriculturalists related to the implications of the word "reduced."

TABLE 1

FREQUENCY OF REPORTED CROPLAND CURRENTLY UNDER SOME FORM OF CONSERVATION TILLAGE ON THE CANADIAN PRAIRIES IN 1990

Percent Conservation Tillage	Frequency Reported
0 - 10%	XXXXXXXXXXXXXXXXX
11 - 20%	XXXXXXXX
21 - 30%	XXX
31 - 40%	XX
41 - 50%	X
51 - 60%	
61 - 70%	X
71 - 80%	X
81 - 90%	X
91 - 100%	X

Note: Based on data from questionnaire returns. Respondents had responsibilities for agricultural land covering approximately 12.3 million hectares.

TABLE 2

FREQUENCY OF REPORTED CROPLAND ESTIMATED TO BE UNDER SOME FORM OF CONSERVATION TILLAGE IN FIVE YEARS ON THE CANADIAN PRAIRIES

Percent Conservation Tillage	Frequency Reported
0 - 10%	XXXXX
11 - 20%	XXXXX
21 - 30%	XXXXXXX
31 - 40%	XXX
41 - 50%	XXX
51 - 60%	XX
61 - 70%	
71 - 80%	X
81 - 90%	XX
91 - 100%	X

Note: Based on data from questionnaire returns. Not all respondents giving estimates for current conservation tillage (Table 1) gave estimates for conservation tillage in 5 years.

TABLE 3

ESTIMATES OF THE FORMS OF CONSERVATION TILLAGE

CURRENTLY IN USE

ON THE CANADIAN PRAIRIES

Form of Conservation Tillage	Range of Responses	Median	Average
Zero Tillage	0% to 10%	2.0%	2.8%
Reduced Tillage	0.5% to 100%	21%	46%
Minimum Tillage	2% to 100%	15%	33%
Chemical Fallow	0.5% to 75%	10%	24%

Note: Based on data from questionnaire returns.

2.5 Consequences of Increased Conservation Tillage Related to Weed Species and Herbicide Use

The literature concerning a change from conventional to conservation tillage is overwhelming in its conclusion that such a shift will cause changes in weed species and increased weed populations. This change will result in an increased reliance on chemical herbicides for the maintenance of crop yields equivalent to those obtained with conventional tillage. Some studies identify increased weed infestations and changes in weed populations specific to various crops. For example, the use of no-tillage practices was confirmed to cause a shift from annual to perennial weed species in corn. Weed species such as Canada thistle (Cirsium arvense), horsenettle (Solanum carolinense), hemp dogbane (Apocynum cannabinum) and common dandelion (Taraxacum officionale) were identified by Triplett and Lytle (1972) as becoming prominent in no-tillage corn. Foxtail barley (Hordeum jubalum) and other perennial weeds can become such a problem in no-tillage cereal crops (e.g. spring wheat, Triticum aestivum) that they are the prime deterrent to conservation tillage in the northern Great Plains of the U.S. and Canada (Donald 1988). A no-tillage corn-sorghum rotation program caused increased annual grass density, but no change in the annual broadleaf weed species (Wruck and Arnold 1985). Weeds such as quackgrass (Agropyron repens), foxtail barley (Hordeum jubatum), green foxtail (Setaria viridis), Russian thistle (Salsola kali), Canada thistle (Cirsium arvense) and kochia (Kochia scoparia) were mentioned by telephone interviewees as potential problem weeds in conservation tillage. The increased potential for the occurrence of herbicide resistance in some weed species was also mentioned as a possible consequence of a shift to conservation tillage systems.

Many reports in the literature demonstrated increased annual grass and perennial weeds in a variety of different climatic regions as a result of the shift from conventional to reduced tillage or no-tillage practices (e.g. Arnold 1976; Kapusta and Stricker 1976; Kapusta 1979; Phillips and Phillips 1984; Brown and Whitwell 1985). As a result, it is taken for granted that reduced tillage and no-tillage cropping systems are accompanied by increased problems with annual grasses and perennial weeds regardless of location. However, it should also be noted that continuous use of the same herbicides on the same site, regardless of tillage practice, has also produced increases in weed population levels

and shifts in the species composition of the weed population (Robertson et al. 1976; Pollard and Cussans 1981; Pareja et al. 1985; Johnson and Coble 1986; Doub et al. 1988). By contrast, the weed population resulting from a shift to conservation tillage practices may not be substantially different from that observed under conventional tillage (Jacques 1983; LaFond et al. 1990).

The change from conventional tillage to conservation tillage may promote increases in weeds or changes in weed species by increases in the weed seed reserve. Soil disturbance is the primary indirect stimulus for weed seed germination. Thus, the weed seeds are stimulated to germinate by tillage and weed seedlings are subsequently killed by continued tillage under conventional tillage practices. By contrast, reduced tillage would be expected to promote retention of large weed seed reserves in soil as the soil disturbance stimulus would be reduced or eliminated. The production of potentially large weed seed reserves could lead to serious weed competition and reduced crop yields (Forcella and Lindstrom 1988). Weed species shifts to perennial broadleaf and grassy weeds as a result of a shift to conservation tillage would be expected, since less soil disturbance would favor weeds that relied on underground reproductive structures for propagation.

Poor herbicidal weed control in reduced tillage systems, which also has been implicated in changes in weed species and populations, has been attributed to the presence of surface crop residue binding the preemergence herbicide (Robertson et al. 1976; Vincent et al. 1978; Wicks et al. 1972). However, other reports credit the surface residue with helping to control weeds (Worsham 1984; Crutchfield et al. 1986; Johnson et al. 1989).

A number of herbicides used in conventional tillage are also used in conservation tillage. A representative, but not comprehensive, list is presented in Table 4. Glyphosate, paraquat and 2,4-D were reported to be the main herbicides used in reduced and no-tillage systems on the Canadian Prairies in 1985 (EPS 1985). Herbicides which must be soil incorporated (e.g. trifluralin, EPTC) are absent from Table 4. The desire to minimize mechanical disturbance of the soil and the presence of crop residues on the soil surface in conservation tillage situations generally prevent the use of soil-incorporated herbicides (EPS 1985; Wagenet 1987). A survey conducted for this report showed that some of the herbicides in Table 4 are currently some of the most frequently used herbicides (Table 5).

Of the 36 herbicides mentioned in the questionnaire returns, 2,4-D stood out as the chemical most frequently used. MCPA (all forms) ranked second and trifluralin third. Bromoxynil and glyphosate followed close behind trifluralin in frequency of use.

It appears from the literature that conservation tillage may promote new mixtures or formulations of existing herbicides according to very crop-specific and weed-specific situations. For example, glyphosate at 0.56 kg a.i./ha plus nonionic surfactant at 0.25% (v/v) did not control perennial foxtail barley in no-tillage, spring-planted cereals in the northern Great Plains. However, adding ammonium sulfate at 2.8 kg/ha to the glyphosate plus surfactant mixture did improve the year-to-year control of this weed (Donald 1988). Combinations of bromoxynil and MCPA, dicamba and 2,4-D, or linuron plus MCPA, are used for problem broadleaf weed control in conservation tillage. Perennial fall weeds in no-tillage systems can be controlled with mixtures of dicamba plus 2,4-D, MCPA, glyphosate or amitrole (EPS 1985).

Estimates for increases in herbicide use with a shift toward conservation tillage depend on the particular form of conservation tillage practiced and crop and weed community. They range from 15 to 60% (Christensen and Norris 1983; Triplett 1985; Wauchope 1987). The wide range of the anticipated increased herbicide use is a result of the fact that herbicide performance in conservation tillage practices cannot be extrapolated from experiences with conventional tillage. Combinations of two or more herbicides are usually required in conservation tillage systems. The choices of herbicides for conservation tillage systems must insure that emerged weeds are killed on contact and weeds from seed germination are killed by herbicides with residual activity (Triplett 1985). Both requirements must be met without damaging or causing yield reductions in the crop being cultivated with the particular conservation tillage system.

Another school of thought among agriculturists maintains that the concurrent development of conservation tillage, and new herbicides and herbicide combinations, will lead to changes in the kinds of herbicide applied, but <u>not</u> total amounts (Fawcett 1987).

TABLE 4

REPRESENTATIVE HERBICIDES USED IN

CONSERVATION TILLAGE SYSTEMS

Common Name	Applied to; Formulation
Atrazine	Soil; aqueous solution or dry granule
Cyanazine	Soil or foliar; aqueous solution
2,4-D (acid)	Soil; aqueous or oil solution
2,4-D (salt)	Soil; aqueous or oil solution
2,4-D (ester)	Soil; aqueous or oil solution
Dicamba (salt)	Foliar spray; aqueous solution
Diuron	Soil; aqueous solution or dry granule
Glyphosate	Foliar; aqueous solution
Hexazinone	Foliar; aqueous solution
Linuron	Soil; aqueous solution
Metolachlor	Soil; aqueous solution
Metribuzin	Soil; aqueous solution
Molinate	Soil; emulsifiable concentrate
Paraquat	Foliar; aqueous solution
Picloram (salt)	Soil or foliar; dry granules or aqueous solutions and sprays
Propachlor	Soil; granular or wettable powder
Propham	Soil; aqueous spray or granular
Simzine	Soil; aqueous solutions or dry granules
Terbutryn	Soil or foliar; aqueous solution

source: Wagenet 1987

TABLE 5

FREQUENCY OF REPORTED CHEMICAL HERBICIDE USE ON THE CANADIAN PRAIRIES IN 1990

Herbicide Common Name	Frequency of Reported Use
Amitrole	X
Benzamide	X
Bentazon	X
Bromoxynil*	XXXXXXXXXXXXXXXXXXXXXXXXXXXXX
Chlorsulfuron	XXXXXXXX
Clopyralid	XXXX
Cyanazine	XXX
2,4-D*	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
Dalapon	XX
Dicamba	XXXXXXXXXXXXXXXXXXXXXXXXX
Diclofop-methyl	XXXXXXXXXXXXXXXXX
Dichlorprop	XXXXXXX
Difenzoquat	XXXXXXXX
EPTC	XX
Ethalfluralin	XXXXX
Fenoxaprop-ethyl	XXXXXXX
Fluazifop-butyl	XXXXXX
Flamprop methyl	XXXXXX
Glyphosate	XXXXXXXXXXXXXXXXXXXXXXXXXX

TABLE 5 (CONTINUED)

FREQUENCY OF REPORTED CHEMICAL HERBICIDE USE ON THE CANADIAN PRAIRIES

Herbicide Common Name	Frequency of Reported Use
Imazamethabenz	XXXX
Linuron	XX
MCPA*	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
MCPB	XX
MCPP	XX
Mecoprop	XXXXXX
Metsulfuron methyl	XXXXX
Metribuzin	XXXX
Paraquat	XXXXX
Picloram	XXXXX
Propanil	XXXXXX
Sethoxydim	XXXXXXXXXX
TCA	XXXXX
Terbacil	X
Triallate	XXXXXXXXXXXXXXXXXXXXX
Trifluralin	XXXXXXXXXXXXXXXXXXXXXXXXXXXXX

* all forms

Note: Based on data from questionnaire returns. Respondents reported the use of Avadex (diallate), but apparently meant Avadex BW (triallate) as diallate is not sold in Canada.

The questionnaire returns mentioned glyphosate most frequently as the herbicide which had the greatest potential to increase in use as a result of a shift toward increased conservation tillage practices (Table 6). The second most frequently mentioned herbicide was 2,4-D. The remaining 13 herbicides identified in Table 6 were mentioned much less frequently than either 2,4-D or glyphosate. A frequent comment in the questionnaire returns, with regard to glyphosate, was that the future use of this herbicide was directly related to its price; the lower the price, the greater the potential for increased use. Some respondents also stated that a shift from conventional tillage to conservation tillage would be accompanied by a shift away from the general category of preemergent herbicides toward post-emergent herbicides. Only one respondent thought that the preemergent herbicide trifluralin would see increased use in conservation tillage practices. This would be trifluralin in a granular formulation.

TABLE 6

HERBICIDES ANTICIPATED TO BE MORE WIDELY USED (WITH FREQUENCY OF RESPONSES) WITH INCREASED CONSERVATION TILLAGE ON THE CANADIAN PRAIRIES

Herbicide	Frequency of Response
Bromoxynil	XXX
Chlorsulfuron	XXXXXXX
2,4-D*	XXXXXXXXXXXXXXXXXXXXXXXXX
Dicamba	XXXXXX
Difenzoquat	X
Diquat	X
Fenoxaprop-ethyl	XXXXX
Fluazifop-butyl	XX
Glyphosate	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
MCPA	XX
Metsulfuron-methyl	XXXXX
Paraquat	XXXXXX
Picloram	X
Sethoxydim	XXXX
Triallate	XX

* all forms

Note: Based on data from questionnaire returns.

2.6 Consequences of Increased Conservation Tillage Related to Insect Pests

Of the various types of conservation tillage reported to promote the presence of insect pests, most are associated with no-tillage practices. Natural plant hosts of some insects can be eliminated by herbicides which control emerged weeds, resulting in insect consumption of the cultivated crop (Gregory and Musick 1976). Corn planted in a no-tillage system into cover crops, such as rye, frequently results in armyworm (Pseudoletia unipuncta) infestations (Musick and Petty 1973; 1974).

Reduced tillage systems, where weed growth is left until planting, may cause greater problems with blackworm (Agrolis ipsilon) as the adult moths are attracted to early spring weed growth. No-tillage corn production also has been reported to increase the presence of the stalk borer (Papaipeme nebris), which overwinters in grasses. In no-tillage systems, the stalk borer can be found in weedy grasses not controlled by herbicides the previous season (Foster 1986).

The data related to the effect of no-tillage corn production and the prevalence of corn rootworm (Diabrotica sp.) is conflicting (Fawcett 1987). Some authors have reported a four-fold increase in rootworm eggs and increased egg survival in no-tillage corn compared to conventional tillage (Musick and Petty 1974; Gray 1986). Other reports found the survival of the eggs and larvae of this insect to be reduced under no-tillage conditions (Musick and Collins 1971). Many species of wireworms and white grubs are present in all tillage systems. However, the lack of mechanical disturbance with no-tillage cropping may enhance the populations of these pests by a reduction in the exposure of these insects to parasites and predators (Phillips 1984).

Whether or not insecticide use will increase in response to a shift toward more conservation tillage is open to question. Use is probably dependent on the specific type of conservation tillage practiced and the weed control program associated with it. Insecticide use with mulch tillage was reported to be identical to conventional tillage, but was significantly greater for no-tillage corn production (Hanthorn and Duffy 1983). A comparison of no-tillage, ridge-tillage and conventional tillage systems for corn and soybean production by Christensen et al. (1985) showed no difference in insecticide usage.

Carbofuran was the most frequently used insecticide according to questionnaire responses, but only at a frequency slightly greater than decamethrin, carbaryl, malathion and chlorpyrifos. These later chemicals were all used at about the same frequency. Other insecticides mentioned by the respondents were dimethoate, permethrin, cypermethrin, deltamethrin, diazinon, trichlorfon, terbufos, gamma BHC, lindane and cygon. The implication of the responses in the returned questionnaires was that little or no change would be expected in insecticide use with a shift toward conservation tillage.

2.7 Consequences of Increased Conservation Tillage Related to Plant Disease

Soil surface crop residues have the potential to increase crop diseases by providing overwintering environments for the survival of pathogens until the next crop is planted. Foliar pathogens, such as Helminthosporium sp., which causes corn leaf blight, are known to survive in the corn residues or mulch of no-tillage systems. In addition, brown spot, caused by Phyllosticla maydis, and grey leaf spot, caused by Cercospora zeae-maydis, are generally diseases which increase in severity with conservation tillage (Fawcett 1987). However, some exceptions to the general rule do exist. Seedling corn diseases have been reported to be equal under conventional tillage, minimum tillage and no-tillage systems (Elliot 1976). In addition to fungi, plant debris on the soil surface also provides for the overwintering of several pathogenic bacteria, which are known to cause blight in soybean and wilt in corn (Fawcett 1987).

Reduced soil temperatures in the spring and early summer, as a result of conservation tillage practices, create the potential for slow germination and seedling development of crop species with the subsequent enhancement of damping off and root disease (Fawcett 1987).

Despite the potential for increased plant diseases in conservation tillage systems, the various reports in the literature concerning this subject are not unanimous in their support for this effect. Wheat diseases have not increased in Nebraska after 10 years of cropping practices, which consistently left crop residues on the soil surface (Wicks and Klein 1985). While no-tillage soybean practices increased populations of the fungus Fusarium in the soil, compared with conventional tillage, the incidence of wilt caused by

this fungus in no-tillage systems was not different from that in conventional tillage systems (Ferrant and Carroll 1979). Minimum tillage techniques have been shown to both increase (Cook et al. 1978) and decrease (Brooks and Dawson 1968) the incidence of take-all disease in wheat and reduced the occurrence of eyespot disease (Brooks and Dawson 1968; Cook and Waldher 1977). The sharp eyespot and brown foot rot fungal diseases of wheat were unaffected by the tillage system (Hood 1965).

Fungicides were not mentioned in return questionnaires with regard to shifts in chemicals associated with a shift away from conventional tillage and toward conservation tillage. Few fungicides were mentioned by questionnaire respondents regarding the current use of these chemicals. Those which were mentioned were maneb, thiram, benomyl, iprodione, captan and carboxin. The implication was that the current use of these chemicals is not anticipated to change dramatically as more crop land is subjected to conservation tillage practices.

3.0 CONCLUSIONS

The weight of evidence from the literature and the results of telephone interviews with knowledgeable individuals, indicated that shifts in the composition of the weed community and possible increases in weed density may occur as a result of a shift from conventional to conservation tillage. However, the available literature also indicated weed population increases and species shifts were the result of local conditions and several interacting factors, including the particular weed management program incorporated into that particular conservation tillage regime.

Any reduced tillage system relies on herbicides to kill those weeds normally killed by tillage. The complete absence of tillage requires complete reliance on herbicides. Thus, herbicide applications will be substituted for tillage operations. This will increase the number of herbicide applications used compared to conventional tillage, but not necessarily the rate at which the herbicides are applied.

Some comments in the literature have implied that the agrochemicals industry will rise to the occasion and develop new herbicides to use in conservation tillage. However, the market must be created by demonstrating that conservation tillage is more economical

and produces equivalent or better crop yields than conventional tillage. Acceptance of conservation tillage by farmers is, of course, paramount in the increased utilization of herbicides. In this regard, other factors such as precipitation, fuel costs and herbicide costs seem to have a major influence on the future acceptance of conservation tillage.

The available literature concerning the increased use of pesticides other than herbicides is not well defined. The specific characteristics of each individual situation appear to be the governing factors which determine whether or not increased use of insecticides or fungicides will be called for when the shift to conservation tillage is made.

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APPENDIX A

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APPENDIX B

QUESTIONNAIRE AND MAILING LIST

CONSERVATION TILLAGE QUESTIONNAIRE SENT TO ALBERTA, MANITOBA AND SASKATCHEWAN AGRICULTURALISTS

1. Approximately how many acres or hectares of agricultural land are you responsible for administering?

2. About what percentage of that agricultural land is under some form of conservation tillage? What do you expect this percentage to be in five years?

3. What are the different types of conservation tillage being practiced in your district? What are their approximate proportions?

4. What brands, trade names or active ingredients of herbicides, insecticides and fungicides are presently being used on agricultural land in your district?

5. Can you give an estimate of the total amount (ie litres, gallons, pounds, kilograms) of each chemical used in those areas under conventional tillage practices and those areas under conservation tillage during one growing season?

6. Which chemicals do you anticipate will become more frequently used as a result of an increase in conservation tillage during the next five years?

Agriculture Fieldman
c/o Mr. Leslie Tailfeathers
Blood Tribe Administration
P.O. Box 52
STANDOFF, Alberta T0L 1T0

Barbara Archibald
District Agriculturist
Alberta Agriculture
P.O. Box 1170
AIRDRIE, Alberta T0N 0B0

Ruth McMorris
District Agriculturist
Alberta Agriculture
802 - 6 Street East
BOW ISLAND, Alberta T0K 0G0

Gordon Frank
District Agriculturist
Alberta Agriculture
P.O. Box 788
BROOKS, Alberta T0J 0J0

Dave Zukerman
District Agriculturist
District Extension Office
Alberta Agriculture
911 - 32 Avenue North East
CALGARY, Alberta T2E 6X6

David Samm
District Agriculturist
Alberta Agriculture
4909C - 48 Street
CAMROSE, Alberta T4V 1L7

Jim Hansen
District Agriculturist
Alberta Agriculture
P.O. Box 670
CARDSTON, Alberta T0K 0K0

Ted Nibourg
District Agriculturist
Alberta Agriculture
P.O. Box 40
CLARESHOLM, Alberta T0L 0T0

Doug Cornell
District Agriculturist
Alberta Agriculture
P.O. Box 160
CORONATION, Alberta T0C 1C0

Gerald Laarhuis
District Agriculturist
Alberta Agriculture
P.O. Box 30
DRAYTON VALLEY, Alberta T0E 0M0

Ron Koots
District Agriculturist
Alberta Agriculture
P.O. Box 2319
DRUMHELLER, Alberta T0J 0Y0

Fred Young
District Agriculturist
Alberta Agriculture
P.O. Box 360
EVANSBURG, Alberta T9E 0T0

Marvin Nakonechny
District Agriculturist
Alberta Agriculture
P.O. Box 90
FAHLER, Alberta T0H 1M0

Ray Maubert
District Agriculturist
Alberta Agriculture
P.O. Box 326
FOREMOST, Alberta T0K 0X0

Dave Ward
District Agriculturist
Alberta Agriculture
9918 - 102 Street
FORT SASKATCHEWAN, Alberta T8L 2C3

Lorne Cole
District Agriculturist
Alberta Agriculture
PO Box 349
HANNA, Alberta
T0J 1P0

Allan Toly
District Agriculturist
Alberta Agriculture
P.O. Box 490
HIGH RIVER, Alberta T0L 1B0

Ted Darling
District Agriculturist
Alberta Agriculture
P.O. Box 700
INNISFAIL, Alberta T0M 1A0

Neil Miller
District Agriculturist
Alberta Agriculture
5718 - 56 Avenue
LACOMBE, Alberta T0C 1S0

Emile de Milliano
District Agriculturist
Alberta Agriculture
P.O. Box 359
LAMONT, Alberta T0B 2R0

Elmer Bittner
District Agriculturist
Alberta Agriculture
P.O. Box 248
LEDUC, Alberta T0C 1V0

Mike Clawson
District Agriculturist
Bag No. 3014
Agriculture Center
LETHBRIDGE, Alberta T1J 4C7

John Van Keulen
District Agriculturist
Alberta Agriculture
770 - 6 Street South West
MEDICINE HAT, Alberta T1A 4J6

John Hladky
District Agriculturist
Alberta Agriculture
P.O. Box 1020
MORINVILLE, Alberta T0G 1P0

Ron Woolf
District Agriculturist
Alberta Agriculture
P.O. Box 250
OLDS, Alberta T0M 1P0

John Ruschowski
District Agriculturist
Alberta Agriculture
P.O. Box 120
OYEN, Alberta T0J 2J0

Bob Lyons
District Agriculturist
Alberta Agriculture
P.O. Box 1356
PINCHER CREEK, Alberta T0K 1W0

Brian Cameron
District Agriculturist
Alberta Agriculture
P.O. Box 70
PONOKA, Alberta T0C 2H0

Agnes Whiting
District Agriculturist
Alberta Agriculture
P.O. Box 600
PROVOST, Alberta T0B 3S0

Lorne Turner
District Agriculturist
Alberta Agriculture
4920 - 51 Street
RED DEER, Alberta T4N 6K8

Ted Ford
District Agriculturist
Alberta Agriculture
5025 - 55 Street
RIMBEY, Alberta T0C 2J0

Ken Ziegler
District Agriculturist
Alberta Agriculture
P.O. Box 1870
ROCKY MOUNTAIN HOUSE, Alberta T0M 1T0

Ty Faechner
District Agriculturist
Alberta Agriculture
P.O. Box 200
RYLEY, Alberta T0B 4A0

Lloyd Giebelhaus
District Agriculturist
Alberta Agriculture
P.O. Box 450
SANGUDO, Alberta T0E 2A0

Bruce Friedel
District Agriculturist
Alberta Agriculture
P.O. Box 157
SEDGEWICK, Alberta T0B 4C0

Glen Werner
District Agriculturist
Alberta Agriculture
Bag 600
STETTLER, Alberta T0C 2L0

Pat Hawkings
District Agriculturist
Alberta Agriculture
4709 - 44 Avenue
STONY PLAIN, Alberta T0E 2G0

John Portail
District Agriculturist
Alberta Agriculture
P.O. Box 640
STRATHMORE, Alberta T0J 3H0

Jack Payne
District Agriculturist
Alberta Agriculture
P.O. Box 640
TABER, Alberta T0K 2G0

Robert Drysdale
District Agriculturist
Alberta Agriculture
P.O. Box 370
THORHILD, Alberta T0A 3J0

Jack Hazelwood
District Agriculturist
Alberta Agriculture
P.O. Box 790
THREE HILLS, Alberta T0M 2A0

Shane Dobson
District Agriculturist
Alberta Agriculture
P.O. Box 487
TWO HILLS, Alberta T0B 4K0

Douwe Smid
District Agriculturist
Alberta Agriculture
P.O. Box 588
VAUXHALL, Alberta T0K 2K0

Josie Van Lent
District Agriculturist
Alberta Agriculture
P.O. Box 600
VERMILION, Alberta T0B 4M0

Dennis Stretch
District Agriculturist
Alberta Agriculture
P.O. Box 480
VULCAN, Alberta T0L 2B0

Rick Klippenstein
District Agriculturist
Alberta Agriculture
P.O. Box 459
WAINWRIGHT, Alberta T0B 4P0

Jim Hironaka
District Agriculturist
Alberta Agriculture
P.O. Box 247
WARNER, Alberta T0K 2L0

A. Khan
Agriculture Representative
Manitoba Agriculture
Box 969
ALTONA, Manitoba
R0G 0B0

E. Taillieu
Agriculture Representative
Manitoba Agriculture
Box 667
CARMAN, Manitoba
R0G 0J0

D. Beernaert
Agricultural Representative
Manitoba Agriculture
Box 532
GLADSTONE, Manitoba
R0J 0T0

B. Nedohin
Agricultural Representative
Manitoba Agriculture
Box 1359
MORDEN, Manitoba

Agricultural Representative
Manitoba Agriculture
Box 100
MORRIS, Manitoba
R0G 1K0

R. McNabb
Agricultural Representative
Manitoba Agriculture
PILOT MOUND, Manitoba
R0G 1P0

Agricultural Representative
Manitoba Agriculture
Box 189
SOMERSET, Manitoba
R0G 2L0

R. Haugh
Agricultural Representative
Manitoba Agriculture
Box 40
STARBUCK, Manitoba
R0G 2P0

R. Wheeler
Agricultural Representative
Manitoba Agriculture
Box 299
TREHERNE, Manitoba
R0G 2V0

J. Maltman
Agricultural Representative
Manitoba Agriculture
P.O. Box 1
DUGALD, Manitoba
R0E 0K0

J. McGregor
Agricultural Representative
Manitoba Agriculture
Box 100
ST. PIERRE, Manitoba
R0A 1V0

H. Richardson
Agricultural Representative
Manitoba Agriculture
Box 760
STEINBACH, Manitoba
R0A 2A0

W. Happychuk
Agricultural Representative
Manitoba Agriculture
Box 10
VITA, Manitoba
R0A 2K0

G. Huebner
Agricultural Representative
Manitoba Agriculture
Box 2000
ARBORG, Manitoba
R0C 0A0

K. Yaworski
Agricultural Representative
Manitoba Agriculture
27 - 2nd Avenue S.W.
DAWSON, Manitoba
R7N 3E5

M. Paziuk
Agricultural Representative
Manitoba Agriculture
ETHELBERT, Manitoba
R0L 0T0

H. Boughton
Agricultural Representative
Manitoba Agriculture
Box 970
ROBLIN, Manitoba
R0L 1P0

Agricultural Representative
Manitoba Agriculture
Box 160
RUSSELL, Manitoba
R0J 1W0

R. Sheldon
Agricultural Representative
Manitoba Agriculture
Box 180
STE. ROSE, Manitoba
R0L 1S0

S. Jersak
Agricultural Representative
Manitoba Agriculture
Box 370
SWAN RIVER, Manitoba
R0L 1Z0

Agricultural Representative
Manitoba Agriculture
Box 2550
THE PAS, Manitoba
R9A 1M4

J. Lapka
Agricultural Representative
Manitoba Agriculture
1129 Queen's Avenue
BRANDON, Manitoba
R7A 1L9

K. Levenick
Agricultural Representative
Manitoba Agriculture
Box 729
BOISSEVAIN, Manitoba
R0K 0E0

M. Frank
Agricultural Representative
Manitoba Agriculture
Box 160
CARBERRY, Manitoba
R0K 0H0

J. Patterson
Agricultural Representative
Manitoba Agriculture
Box 50
HAMIOTA, Manitoba
R0M 0T0

L. Enns
Agricultural Representative
Manitoba Agriculture
Box 190
KILLARNEY, Manitoba
R0K 1G0

D. Southam
Agricultural Representative
Manitoba Agriculture
Box 519
MELITA, Manitoba
R0M 1L0

J. Findlay
Agricultural Representative
Manitoba Agriculture
Box 1198
MINNEDOSA, Manitoba
R0J 1E0

B. Durston
Agricultural Representative
Manitoba Agriculture
Box 670
NEEPAWA, Manitoba
R0J 1H0

B. Lambert
Agricultural Representative
Manitoba Agriculture
Box 100
SHOAL LAKE, Manitoba
R0J 1Z0

M. Archambault
Agricultural Representative
Manitoba Agriculture
Box 850
SOURIS, Manitoba
R0K 2C0

J. Hollinger
Agricultural Representative
Manitoba Agriculture
Box 850
VIRDEN, Manitoba
R0M 2C0

G. Noble
Extension Agrologist
Saskatchewan Rural Development
Box 250
ASSINIBOIA, Saskatchewan
S0H 0B0

W. Kehler
Extension Agrologist
Saskatchewan Rural Development
Box 250
ASSINIBOIA, Saskatchewan
S0H 0B0

B. Sim
Extension Agrologist
Saskatchewan Rural Development
Box 658
CANORA, Saskatchewan
S0A 0L0

G. Barclay
Extension Agrologist
Saskatchewan Rural Development
Box 1145
BIGGAR, Saskatchewan
S0K 0M0

G. McLean
Extension Agrologist
Saskatchewan Rural Development
Box 339
CARNDUFF, Saskatchewan
S0C 0S0

M. Ruszkowski
Extension Agrologist
Saskatchewan Rural Development
Box 693
DAVIDSON, Saskatchewan
S0G 1A0

B. Hansen
Extension Agrologist
Saskatchewan Rural Development
1219 - 5th Street
ESTEVAN, Saskatchewan
S4A 0Z1

D. Simmons
Extension Agrologist
Saskatchewan Rural Development
Box 579
FORT QU'APPELE, Saskatchewan
S0G 1S0

D. Perrault
Extension Agrologist
Saskatchewan Rural Development
Box 609
HUDSON BAY, Saskatchewan
S0E 0Y0

E. Tanner
Extension Agrologist
Saskatchewan Rural Development
Box 399
INDIAN HEAD, Saskatchewan
S0G 2K0

W. Vanin
Extension Agrologist
Saskatchewan Rural Development
Box 2080
KANSACK, Saskatchewan
S0A 1S0

L. Gutek
Extension Agrologist
Saskatchewan Rural Development
Box 250
KELVINGTON, Saskatchewan
S0A 1W0

B. Green
Extension Agrologist
Saskatchewan Rural Development
Box 678
KERROBERT, Saskatchewan
S0L 1R0

B. Rapp
Extension Agrologist
Saskatchewan Rural Development
Box 1690
KINDERSLEY, Saskatchewan
S0L 1S0

G. Ivanochko
Extension Agrologist
Saskatchewan Rural Development
Box 5000
LA RONGE, Saskatchewan
S0J 1L0

L. Schafer
Assistant Extension Agrologist
Saskatchewan Rural Development
Box 397
LEADER, Saskatchewan
S0N 1H0

H. Bjorge
Extension Agrologist
Saskatchewan Rural Development
4815 - 50th Street
LLOYDMINSTER, Saskatchewan
S9V 0W8

D. Tumbach
Extension Agrologist
Saskatchewan Rural Development
Box 938
MAPLE CREEK, Saskatchewan
S0N 1N0

D. Cubbon
Extension Agrologist
Saskatchewan Rural Development
Box 369
MEADOW LAKE, Saskatchewan
S0M 1V0

A. Stewart
Extension Agrologist
Saskatchewan Rural Development
Box 6500
MELFORT, Saskatchewan
S0E 1A0

D. Struthers
Extension Agrologist
Saskatchewan Rural Development
Box 10
MELVILLE, Saskatchewan
S0A 2P0

J. Graham
Extension Agrologist
Saskatchewan Rural Development
Room 118
110 Ominica Street W.
MOOSE JAW, Saskatchewan
S6H 6V2

Jim Pollock
Extension Agrologist
Saskatchewan Rural Development
Box 239
MOOSOMIN, Saskatchewan
S0G 3N0

L. Lee
Extension Agrologist
Saskatchewan Rural Development
Box 2166
KIPAWIN, Saskatchewan
S0E 1E0

H. Nickel
Extension Agrologist
Saskatchewan Rural Development
509 Pioneer Avenue
NORTH BATTLEFORD, Saskatchewan
S9A 1E9

B. Hurd
Extension Agrologist
Saskatchewan Rural Development
Box 9
OUTLOOK, Saskatchewan
S0L 2N0

B. Swanson
Extension Agrologist
Saskatchewan Rural Development
Box 3003
PRINCE ALBERT, Saskatchewan
S6V 6G1

K. Pedersen
Extension Agrologist
Saskatchewan Rural Development
2024 Albert Street
REGINA, Saskatchewan
S4P 3V7

J. Ippolito
Extension Agrologist
Saskatchewan Rural Development
Box 640
ROSETOWN, Saskatchewan
S0L 2V0

L. Bader
Extension Agrologist
Saskatchewan Rural Development
Box 538
ROSTHERN, Saskatchewan
S0K 3R0

B. Rugg
Extension Agrologist
Saskatchewan Rural Development
3130 - 8th Street E.
SASKATOON, Saskatchewan
S7K 2H6

R. Springer
Extension Agrologist
Saskatchewan Rural Development
Box 220
SHAUNAVON, Saskatchewan
S0N 2M0

N. Amundson
Extension Agrologist
Saskatchewan Rural Development
Box 1000
SHELLBROOK, Saskatchewan
S0J 2E0

K. Beaulieu
Extension Agrologist
Saskatchewan Rural Development
Box 130
STRSBOURG, Saskatchewan
S0G 4V0

P. Gerwing
Extension Agrologist
Saskatchewan Rural Development
350 Cheadle Street W.
SWIFT CURRENT, Saskatchewan
S9H 4G3

M. Ayers
Extension Agrologist
Saskatchewan Rural Development
Box 1480
TISDALE, Saskatchewan
S0E 1T0

V. Matschke-Muller
Extension Agrologist
Saskatchewan Rural Development
Box 207
TURTLEFORD, Saskatchewan
S0M 2Y0

L. Klein
Extension Agrologist
Saskatchewan Rural Development
Box 480
UNITY, Saskatchewan
S0K 4L0

T. Boyle
Extension Agrologist
Saskatchewan Rural Development
Box 70
WAXAV, Saskatchewan
S0K 4P0

B. Doig
Extension Agrologist
Saskatchewan Rural Development
Box 1128
WATROUS, Saskatchewan
S0K 4T0

Norman Janssen
Extension Agrologist
Saskatchewan Rural Development
Box 159
WATSON, Saskatchewan
S0K 4V0

E. Moats
Extension Agrologist
Saskatchewan Rural Development
110 Souris Avenue
Box 2003
WEYBURN, Saskatchewan
S4H 2Z9

L. Reeve
Extension Agrologist
Saskatchewan Rural Development
Box 580
WYNARD, Saskatchewan
S0A 4T0

J. Donovan
Extension Agrologist
Saskatchewan Rural Development
A.G. Kuziak Building
YORKTON, Saskatchewan
S3N 2Y4

APPENDIX C

INDIVIDUALS CONTACTED BY TELEPHONE

Mr. Danial McCain
Conservation Tillage Information Centre
1220 Potter Drive
Room 120
Purdue Research Park
West Lafayette, IN
47906-1334
(317) 494-9555

Mr. Walter Yarish
Weeds Group
Alberta Agriculture
Edmonton, Alberta
(403) 427-7098

Dr. A.E. Smith
Agriculture Canada
Regina Research Station
Regina, Saskatchewan
(306) 780-7400

Mr. Gordon Thomas
Agriculture Canada
Regina Research Station
Regina, Saskatchewan
(306) 780-7412

Mr. Lyle Samson
General Manager
Manitoba-North Dakota Zero-Till Association
Minot, North Dakota
(701) 852-8895

Mr. Kenneth Gaudy
Focus on Inputs
Melfort, Saskatchewan
1-800-667-0033

Mr. George Crawford Jenkins
Chief, Soils & Crops Management Branch
Manitoba Agriculture
Brandon, Manitoba
(204) 726-9555

Mr. Larry Slavinsky
Manitoba Agriculture
Winnipeg, Manitoba
(204) 945-2161

Mr. Gui LaFond
Indian Head Experimental Farm
Indian Head, Saskatchewan
(306) 695-2274

Mr. Grant McCallum
Manager, East Central Saskatchewan Soil Conservation Project
Regina, Saskatchewan
(306) 786-1504